Nov. 26, 1935. V. S. MAKAROFF 2,022,137

ARMOR PIERCING PROJECTILE, INCLUDING A METHOD OF INCREASING ITS PIERCING POWER

Filed Jan. 27, 1934 2 Sheets-Sheet 1

Fig. 1.

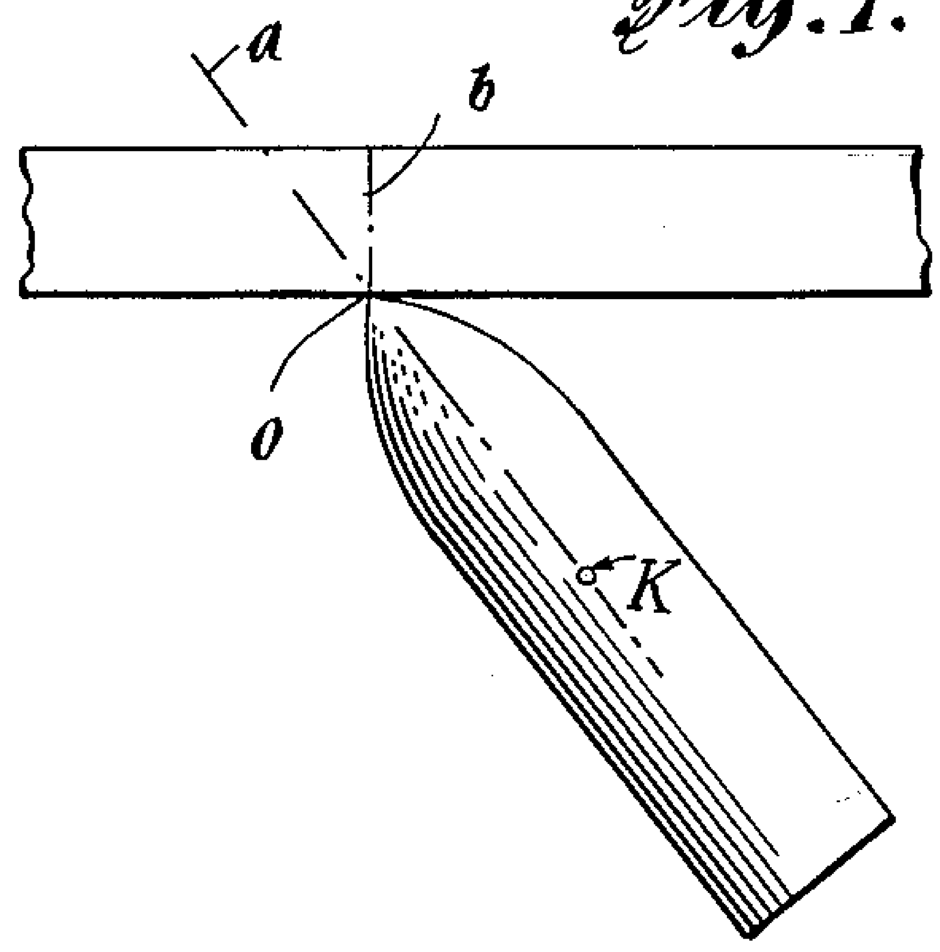


Fig. 2.

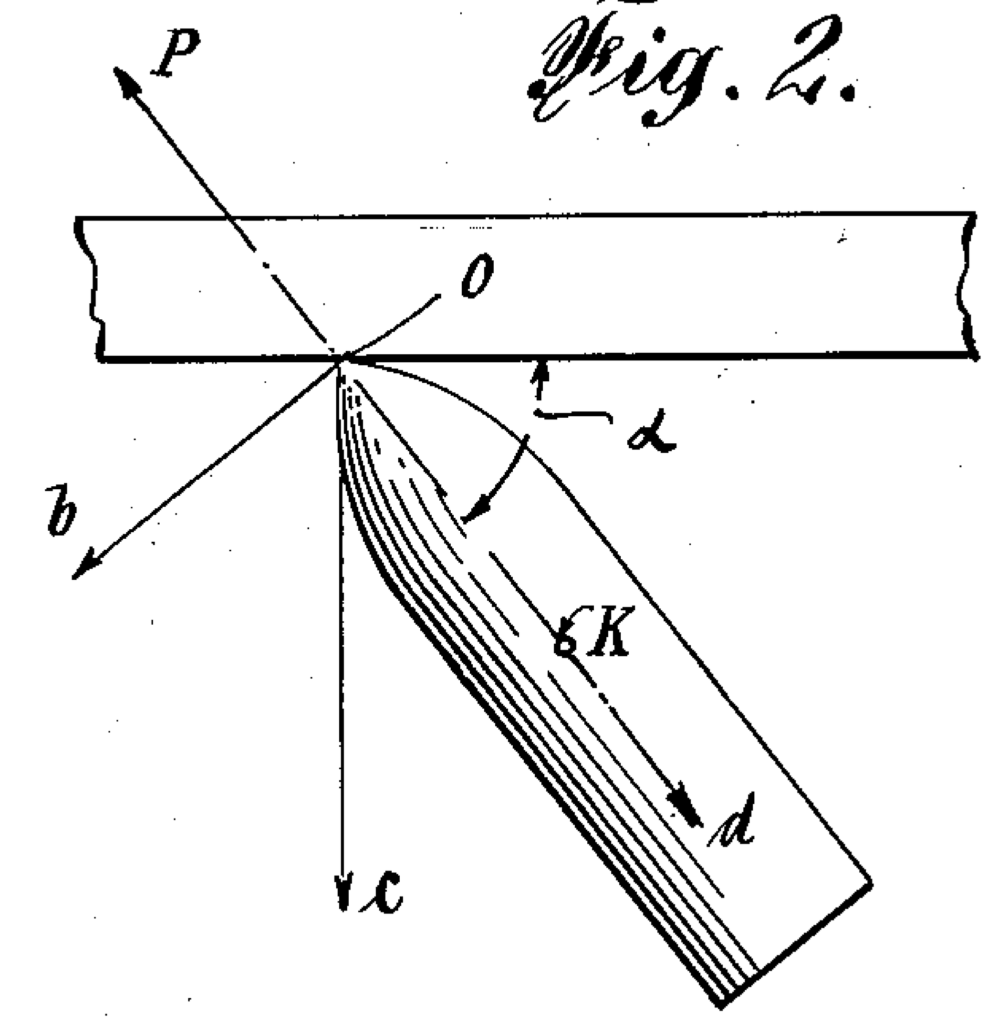


Fig. 3.

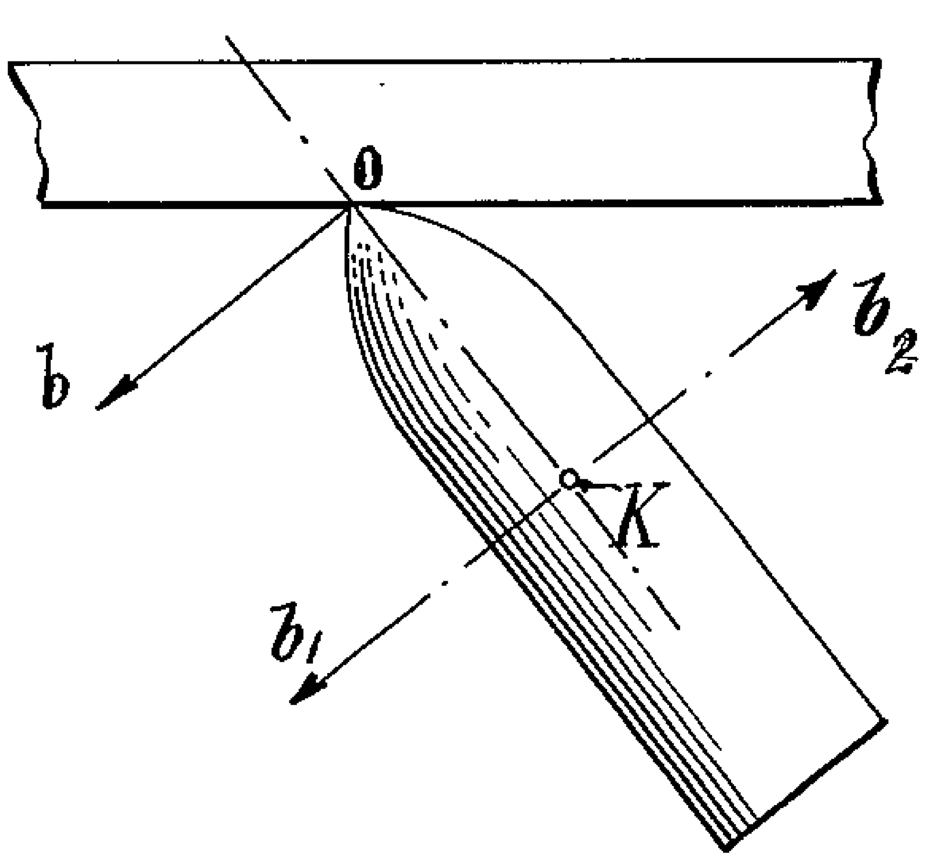


Fig. 4.

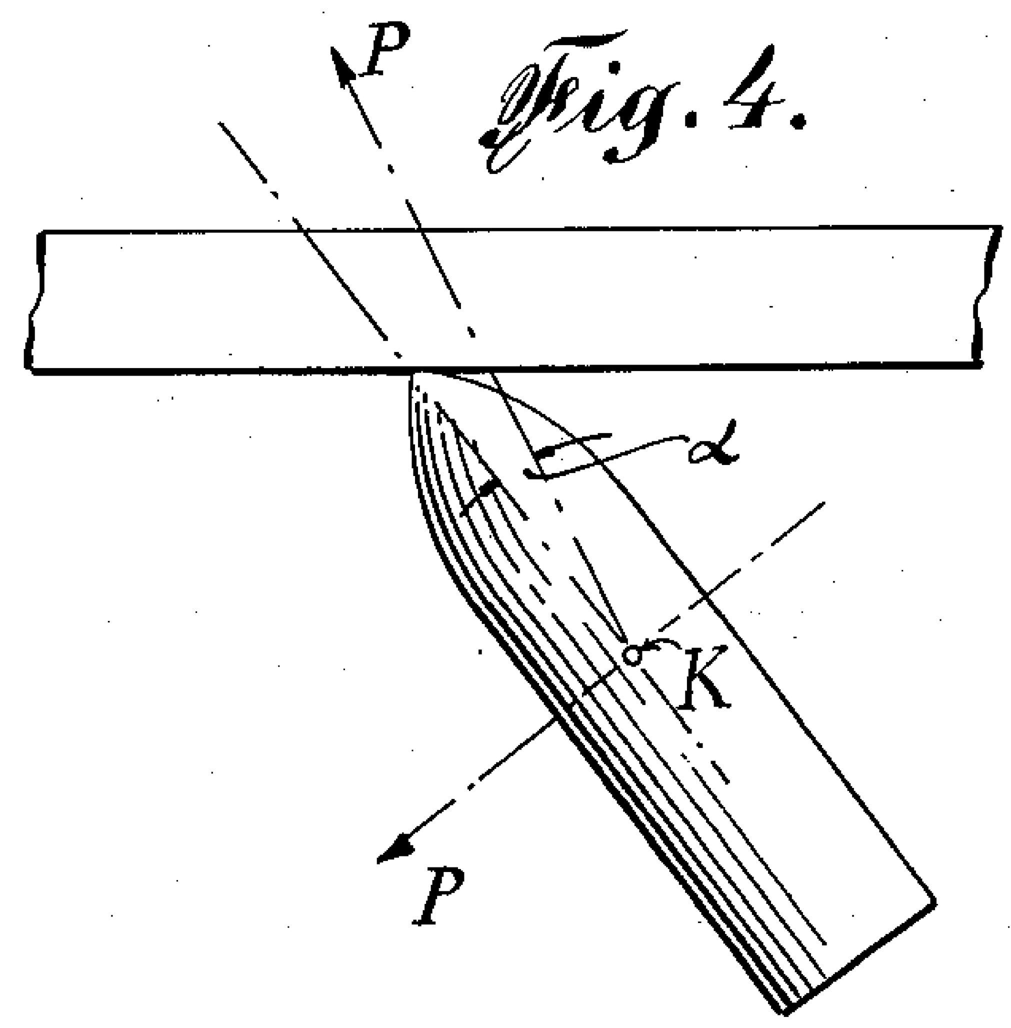


Fig. 5.

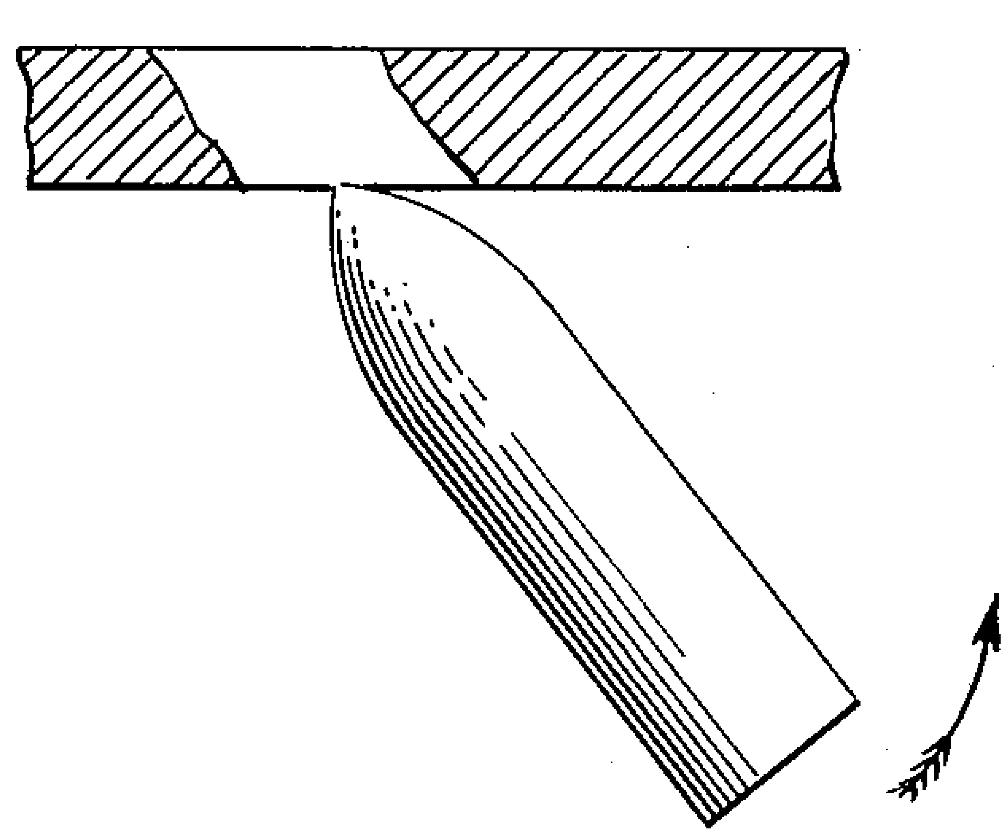
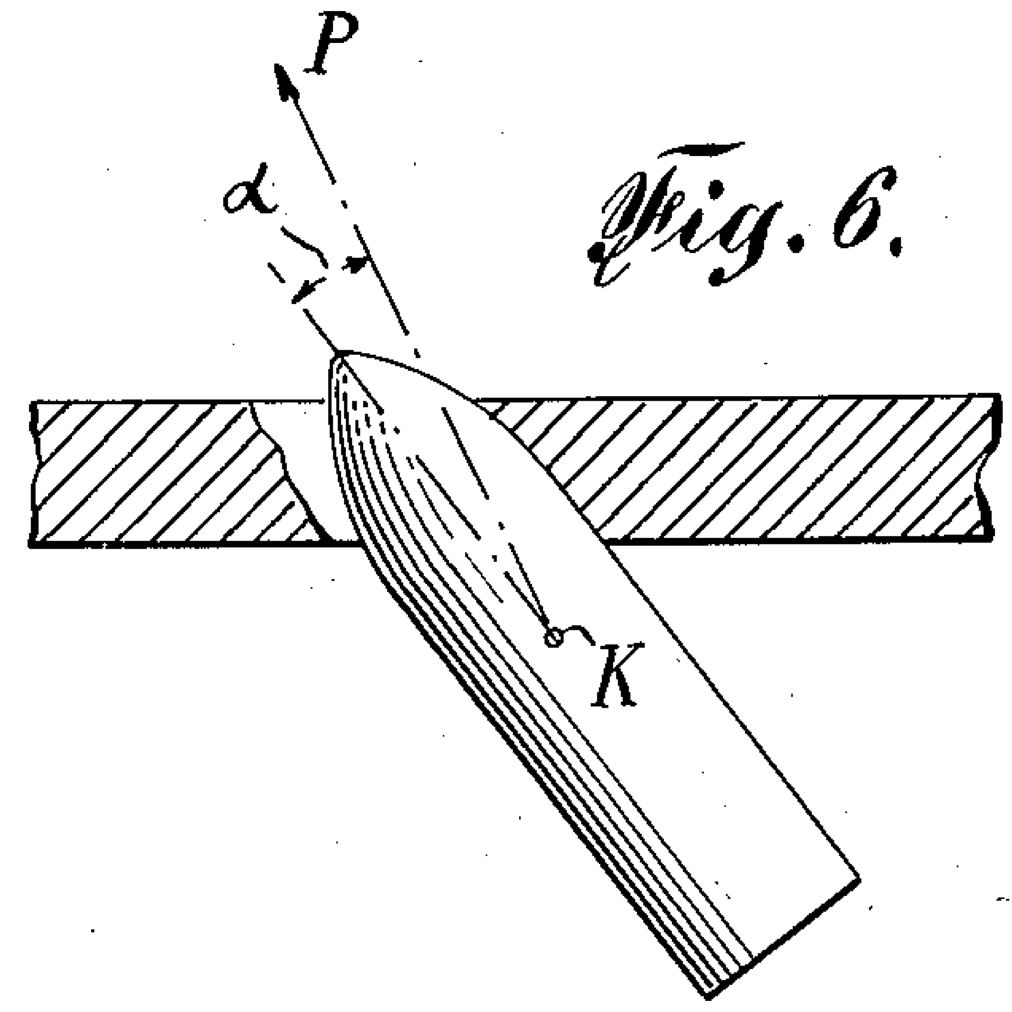


Fig. 6.



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ARMOR PIERCING PROJECTILE, INCLUDING A METHOD OF INCREASING ITS PIERCING POWER

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Fig. 7.

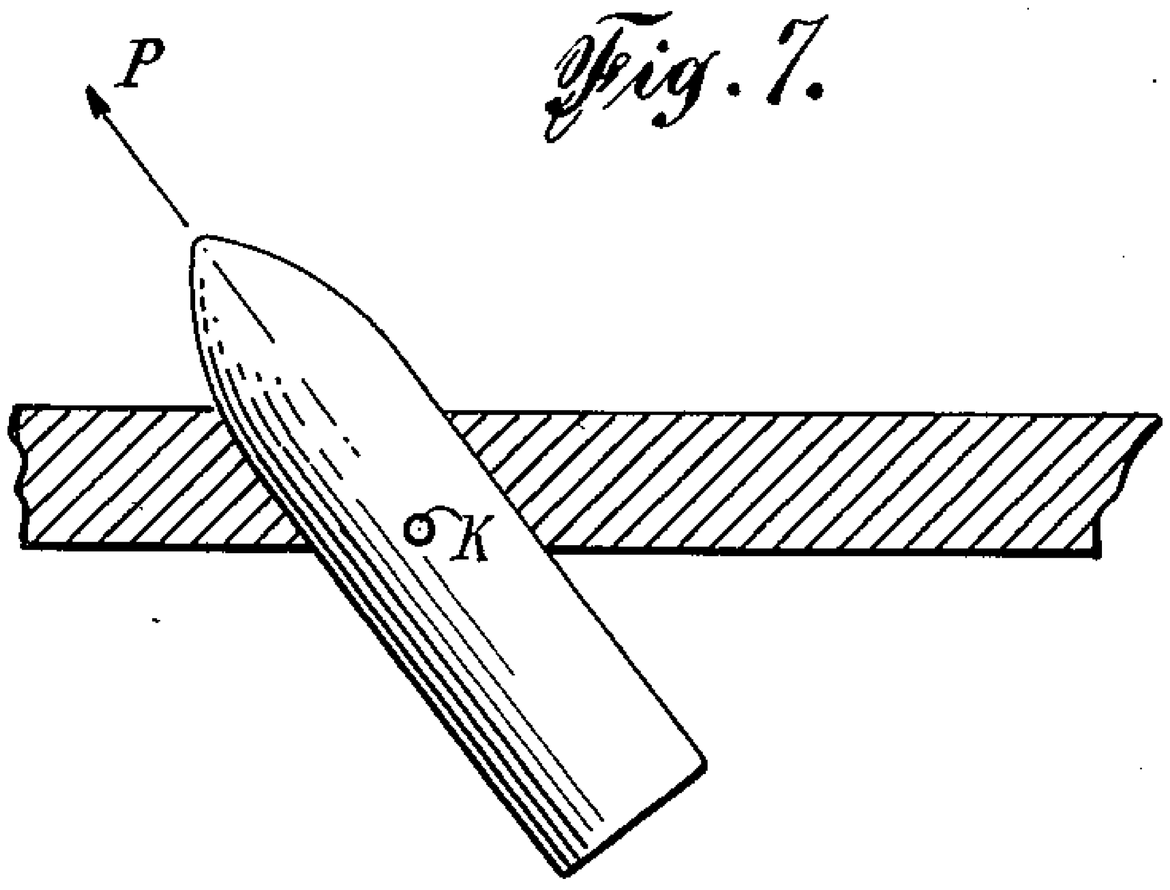


Fig. 8.

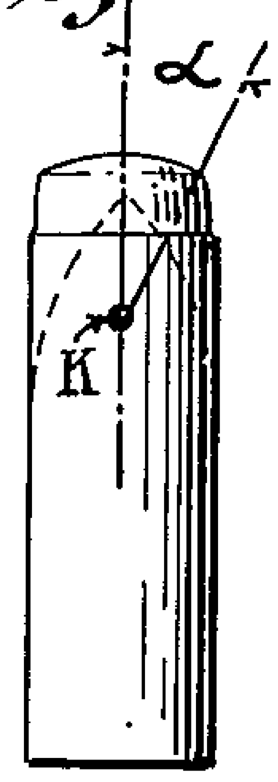


Fig. 9.

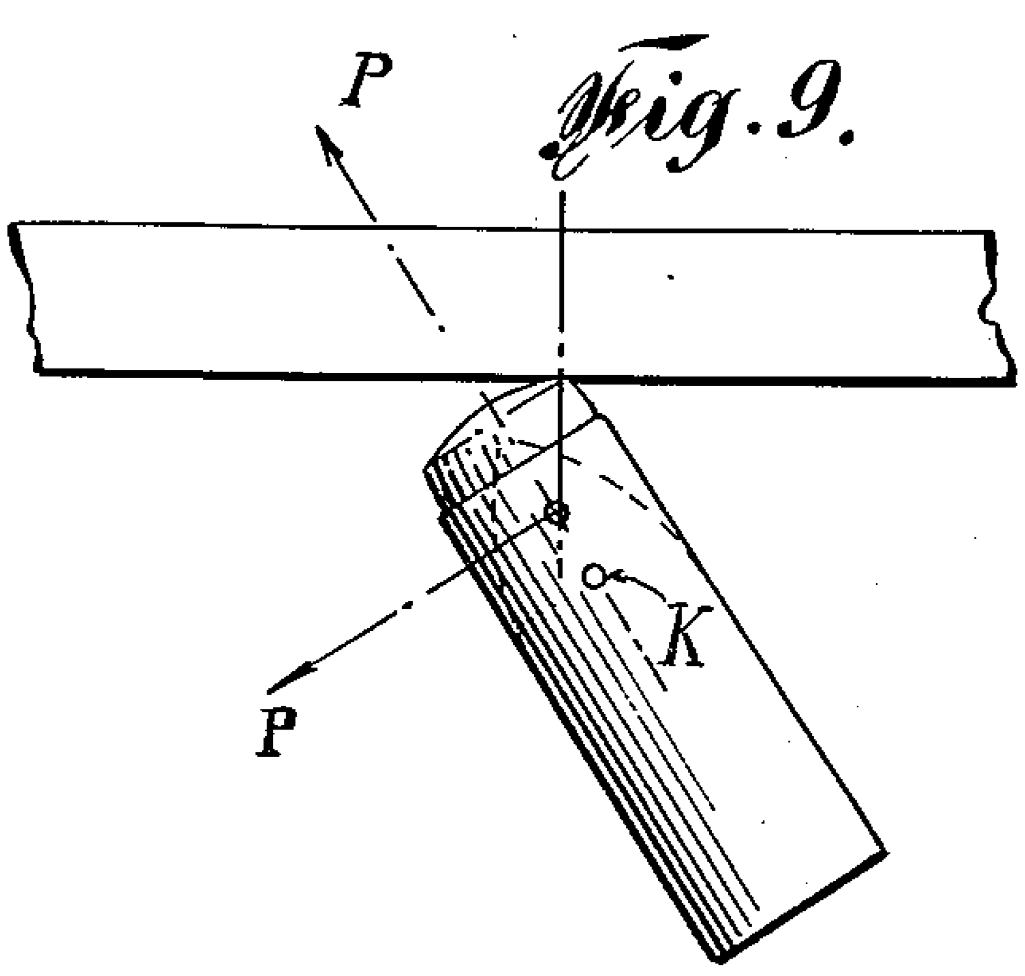
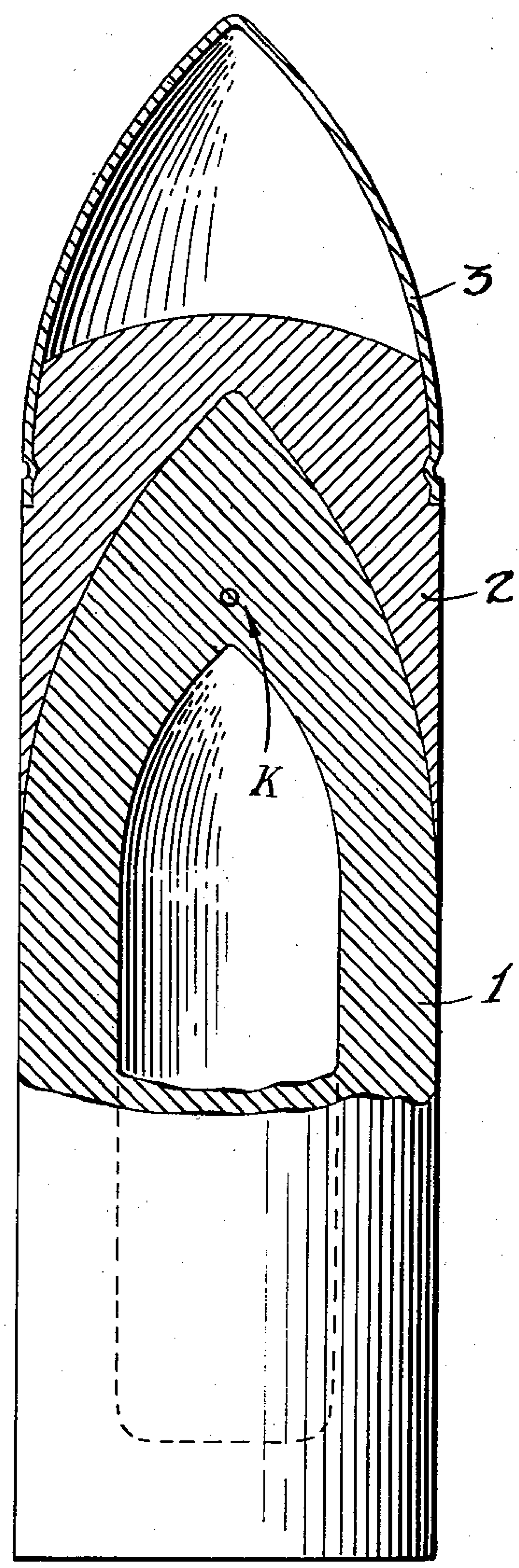


Fig. 10.



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UNITED STATES PATENT OFFICE

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ARMOR PIERCING PROJECTILE, INCLUDING A METHOD OF INCREASING ITS PIERCING POWER

Vadim S. Makaroff, Oyster Bay, N. Y.

Application January 27, 1934, Serial No. 708,552

13 Claims. (Cl. 102—28)

This invention relates to high velocity projectiles and to methods of manufacture which increase their power to penetrate hard substances.

It concerns more particularly a shell of greater puncturing efficiency having a steel cap forward of its piercing point said cap having a front surface of spherical contour, this spherical surface being preferably generated from the shell's center line and from a center point on said center line which should be the center of gravity of said shell.

Armor piercing shells are generally roughly forged from a billet of alloy steel, then they are annealed, bored, turned to shape outside and tempered by a suitable hardening process. After such manufacturing operations have been completed, a steel cap is placed over the front or pointed end of the shell, and on the forward end of said cap a so called "ballistic nose" is fitted to assist the shell aerodynamically in its travel from a gun to the object to be penetrated.

Before my invention, shells were designed and built about as follows:

The tempered and hardened front end of an alloy steel shell terminated in an armor piercing point forming one end of an arc of a circle, extending from and tangent to the shell's relatively straight and substantially parallel sides. A steel cap of similar shape on its forward surface would then be applied to said tempered and hardened front end of the shell and in front of this cap a ballistic nose would be fitted made of stamped and pressed or molded metal.

My projectile or shell is made in much the same way with one difference; that is, that after the shell has been bored and its outer surface finished and tempered, and after the steel cap has been put in place; the point or spot on the center line of the shell, which point is the shell's center of gravity, is carefully determined and a spherical surface is developed and cut as the front (or forward face) of the steel cap, prior to the positioning of a sheet metal (or a molded metal) ballistic streamlined aerodynamic nose placed in front of the rounded cap.

The main object of my invention is to improve the initial "bite" of a projectile into any hard surface or substance to be penetrated by changing its design and construction, reducing the tendency for the shell to slide on the surface to be pierced at the instant of impact, thus increasing the percentage and number of target penetrations at any reasonable angle at which a shell would hit the surface to be penetrated.

My invention, as applied to the design and construction of projectiles, decreases the percentage of shells whose hardened steel pointed armor plate piercing front ends are either partially fractured or entirely broken due to their tendency to rotate unevenly while they are trying to penetrate a surface of hardened steel armor plate.

Due to the rifling of practically all guns firing high velocity projectiles, such projectiles arrive at their target whirling rapidly.

In observing numerous firing tests of shells it occurred to me that on an oblique impact, the nose of the shell is deflected from the trajectory and the shell has a tendency to push its way through the plate sideways. In other words, the shell, after the impact, acquires a rotation around an axis situated on a vertical plane going through the trajectory. It is this rotation that is discussed heretofore and it should not be confused with the whirling of the shell due to the rifling of guns.

The problem appeared to be:— Why did this sidewise rotation occur, causing the shell after it was fired either to glance from the target without biting it, or have its hardened pointed head cracked or broken without penetration, or perhaps, prior to penetration.

The various aspects of this problem and the means and method I employ to solve it, appear in this present specification, in the drawings of which:

Figure 1 shows the usual projectile at the moment of impact.

Figure 2 illustrates the forces acting on the shell at the moment of impact.

Figure 3 indicates the forces tending to rotate the shell horizontally about itself at impact.

Figure 4 shows the natural resultant force P, theoretically but not actually passing through the shell's center of gravity K.

Figure 5 shows the normal simple rotation of a shell due to the rifling of the gun barrel from which the shell was fired.

Figure 6 illustrates a shell in the process of piercing an armor plate.

Figure 7 pictures a shell having fully penetrated an armor plate.

Figure 8 is a side elevational view of a shell made in accordance with my present invention.

Figure 9 is my present form of shell at the moment of impacting an armor plate showing the natural resultant force passing actually through the shell's center of gravity, thus eliminating the usually objectionable horizontal rotation of the shell which prevents the shell getting its proper bite into the armor plate.

Figure 10 is a detailed view of my armor piercing projectile as it is preferably designed and constructed, comprising shell 1, surmounted by armor piercing cap 2, (spherically surfaced over its forward end) which cap is again surmounted by a thin sheet metal shell 3, which at the moment of impact, sluffs off and is actually used merely for aerodynamic low wind resistance purposes.

When witnessing ballistic tests, one gets the impression that there is a big difference in the strains suffered by a shell piercing the plate at an oblique impact in comparison with a shell going through the plate normally.

Even at 10° test, one may notice that the impact is in most cases larger than a normal one and that the shell bears more fractures and evidence of blows than a shell that pierces the plate normally.

It may be a matter of interest to look into the reasons that produce the extra strains and to see to what extent they can be gotten rid of.

There are two reasons that make a shell experience greater strains on an oblique impact than at a normal one. The first is the increase in the width of the plate that has to be penetrated and the second, the rotating movement given to the shell that penetrates through the plate at an angle differing from normal.

If a shell strikes at an angle, it has to force its way through the plate in the direction of Oa (Figure 1) and, therefore, has to pass through the plate a distance Oa. It can be easily calculated that the increase in the width of the oblique impact over the normal one at the same plate is equal to 2% of thickness of the plate at 10°. 6% at 20° and 15% at 30°. Those numbers can not be considered to be large, and, therefore, it may be thought that the increase in the width of the impact is not the main reason of the additional strains on the shell hitting the plate at an angle other than normal.

It is practically impossible to determine to any point of accuracy the impulses acting upon a shell during the time of penetration through the plate, but a study of an impact of two elastic bodies may give us the character of those impulses. For this purpose we may suppose that the shell hits the plate with the energy p (Figure 2), Oc will be the reaction of the plate that we may consider as a resultant of impulses Ob and Od. Od will decrease the shell's speed. Ob we can consider as a resultant of the couple b_1.O. OK. KO_2. with a moment M (Figure 3) and of the impulse $Kb_1=p$ applied to the center of gravity K.

The moment M will give a rotation to the shell around thhe vertical axis passing through the center of gravity. The impulse p will drive the shell to the left. As nothing is known about the velocity of a shell after it pierces a plate, the reaction of the plate can hardly be determined. It will probably amount to a large extent as if by example we suppose that a shell weighing one-half a ton and having 2000 ft. of striking velocity decreased its velocity after piercing the plate to 1000 ft., the reaction will amount to 500 ton f. s.

If we apply an impulse of 500 t. f. s. to the point of the cap of the shell in the direction of the reaction of the plate, the impulse p, if the shell hits the plate at 10°, will be equal to 500, Sin. 10°=90 t. f. s. and the angular velocity of rotation considering roughly that the center gravity is at a distance of 2′ from the point of the cap, and the moment of inertia of the shell will be ½ t. f., will be

$$=\frac{90.2}{\frac{1}{2}}-360\ \frac{\text{radians}}{\text{seconds}}\ \text{or}\ \frac{360}{2}=57$$

revolutions per second. Therefore during the time the shell will pass a distance equal to half of its length (2′) the shell will make

$$\frac{57}{1000}$$

revolutions or change its direction to

$$\frac{57.360}{1000}=20°$$

Coming to the problem of a shell that is piercing the plate one may suppose that the shell is affected by impulses of the same character as described above.

The rotation resulting from the moment M may be severely reduced if the nose of the shell is well forced in the plate, but, on the other hand, one may think that between the moment that the cap hits the plate and the moment the nose of the shell is forced into the plate, while the fragments of the cap are loose around the nose of the shell, the shell starts to rotate around an axis passing through the center of gravity in the direction of the pointer A (Figure 2), and after the nose is forced into the plate, the swinging continues around an axis, passing near to the nose of the shell, and, therefore, the shell makes an effort to pass through the plate sideways.

If we consider this hypothesis correct, there will exist the following characteristic positions of the shell during the piercing of a plate:

1. A plug in the plate is pushed through by the cap. The shell begins rotating in the direction indicated by pointer A (Figure 5).

2. The shell forces its way through the hole sideways. In this time the right side of the shell probably suffers severe strains.

3. After the center of gravity K passes the plate, the pressure of the right side of the impact makes the shell change the direction of its rotation. The shell begins to rotate in the direction opposite to the pointer A and finally hits the left side of the impact by its bottom.

The aspect of the impact confirms this theory as in a case like the one described, the impact is of an oval shape and bears evidence of blows on the right side. The fractures on a shell after it punctures a plate also give us the same conclusions, as—

The nose of the shell in most cases is broken, breaks sometimes later, or develops cracks, all looking like the result of a side blow.

One side of the shell is badly scratched, the scratches being deeper in the middle than on the ends.

The bottom of the shell is fractured on the side opposite the scratches.

The impact is coppered only on the left side.

The impulse p may also create a rotation, after the nose of the shell is forced into the plate. The direction of this rotation will be opposite to the one indicated by the pointer A. But as the impact and the shell bear evidences of a rotation in the direction of the pointer, we may think that the rotating effect of the impulse p is comparatively small.

In order to avoid the rotation resulting from an oblique impact it may be considered an improvement if the cap of the shell should have a spherical surface on the top, radius R of the sphere being equal to the distance between the top and the center of gravity (Figure 8). In this case if the shell hits a plate at the angle equal or smaller than the angle a of the Figure 8, the reaction of the plate will pass, as shown in Figure 9, through the center of gravity K. In this case we will get rid of the moment M of a shell with a pointed cap. If the angle is bigger than the angle a, it is obvious that the moment will exist, but will be much smaller than if the cap were pointed.

The impulse p that is driving the projectile to the left will, of course, remain, and, possibly when the nose of the shell is well forced in the plate, its presence will give the shell an inclination to rotate, but perhaps this rotation can be neutralized by decreasing radius R, therefore, bringing a little moment M back into action.

In other words, the rotation of the shell around a vertical axis at the time of its impact can be controlled by changing the radius R or shifting the position of the center of the spherical surface of the cap in relation to the center of gravity of the shell (or projectile) and the cap combined.

Some efforts have been previously made to improve the so-called "bite" of a shell.

The bite of the shell is quite essential, as it takes care of the sliding of the point of the cap at an oblique impact.

The sliding results from two factors:

1. The sliding of the point of the cap with a velocity V_1, influenced by the impulse P.

2. The sliding of the point of the cap with a velocity V_2, influenced by the moment M.

The total velocity of sliding is $V=V_1-V_2$.

In the example discussed in the memorandum, p is equal to 90 t. f. s. therefore

$$V=\frac{90}{\frac{1}{2}}=180 \text{ f. s.}$$

The moment M gives 57 revolutions to the shell therefore, the velocity $V_2=57.2=715\ f$.

The total velocity of sliding will be

$$V=V_1-V_2=280-715=895 \text{ and } V_2=0,8V.$$

Though it is obvious that the reaction of the plate before the point of the cap is forced in the plate, is much smaller than the 500 t. f. taken as example, the formula $V_2=0,8V$ will be right, disregarding the size of the reaction.

Therefore, we can suppose that if we supply a shell with a spherical cap, we get rid of the sliding V_2 produced by the moment M, and in this manner get rid of 0, 8 of V, the total sliding velocity, in other words improve the "bite" to 80%.

Two expressions, "approximate center of gravity" and "substantially at the center of gravity" are used in the claims of this patent application.

The words "approximate" and "substantially" refer to a point as a center from which a spherical surface is cut and/or measured, such a point being within a distance in any direction from the actual center of gravity of a loaded and/or completely finished projectile, said distance measuring or being equal to any distance up to and/or equal to within and/or including five (5%) of the full length of the completely finished projectile with its cap, as measured on the longitudinal centerline of the loaded and capped projectile.

It is within the scope of the present invention to vary the center of gravity of the shell once it is made, by shifting weights, by varying the weight of the cap or the ballistic nose or by any other suitable method or means, as a definite method of reducing or increasing the rotation of said projectile around its vertical axis, at the time of its final impact with any surface to be penetrated.

I claim:

1. An armor piercing projectile having a spherical surfaced cap, said spherical surface on said cap being generated from a point as a center which is located substantially on the centerline of said projectile and at approximately the center of gravity of said combined projectile and cap.

2. An armor piercing projectile having an armor piercing point covered by a spherical surfaced cap, said spherical surface on said cap being generated from a point as a center which is located substantially on the centerline of said projectile and at approximately the center of gravity of said combined projectile and cap.

3. An armor piercing projectile having an armor piercing point of alloy steel suitably hardened and a steel spherical surfaced cap of less hardness than the temper of said piercing point, said spherical surface on said cap being generated from a point as a center which is located substantially on the centerline of said projectile and at approximately the center of gravity of said combined projectile and cap.

4. A projectile having a tempered point of one hardness and a spherical surfaced cap covering said point said cap of less hardness than said point, said spherical surface on said cap being generated from a point as a center which is located substantially on the center line and at the center of gravity of said projectile.

5. A spherical surfaced cap for pointed projectiles said spherical surface being generated from a point as a center, which point is substantially on the center line of said cap, said spherical surface on said cap being generated from a point as a center which is located substantially on the center line and at the center of gravity of said projectile.

6. A spherical surfaced cap for pointed projectiles, said spherical surface on said cap being generated from a point as a center which is located substantially on the center line of said projectile and at the approximate center of gravity of said projectile.

7. A projectile having a spherical surfaced cap, said spherical surface of said cap being described by a radius extending from a center located on the center line of said projectile, at the center of gravity of said projectile.

8. A projectile having a spherical surfaced cap, said spherical surface of said cap being described by a radius extending from a center which is substantially the center of gravity of said projectile.

9. A projectile having a spherical surfaced cap, said spherical surface of said cap being described by a radius extending from the center of gravity of said projectile.

10. A projectile having a spherical surfaced cap, said projectile carrying in its interior an explosive charge, the spherical surface of said cap being generated from a center which corresponds with the center of gravity of said loaded projectile.

11. A method of increasing the armor piercing power of a projectile comprising the steps of forming the inside and outside surface of said projectile, fastening a cap on the pointed end of said projectile, loading said projectile, determining the center of gravity of said loaded projectile and

forming a spherical surface on said cap with its center at the center of gravity of said loaded and capped projectile.

12. A method of increasing the armor piercing power of a projectile comprising the steps of forming the inside and outside surface of said projectile, loading said projectile, determining the center line and the center of balance of said projectile on said centerline of said loaded projectile and forming a spherical surface on said cap with the center of said surface at said center of balance.

13. A method of increasing the piercing power of a projectile comprising the steps of forming a pointed projectile having a cap over the point of said projectile, loading said projectile, determining the center of gravity of said loaded projectile and shaping a spherical surface on said cap from said center of gravity as a center.

VADIM S. MAKAROFF.